Remarks:

Two sheets of informal drawings that illustrate the method and the device claimed in the present application and described in the specification as filed were added to the application. The drawings are based on the information provided in the application from which priority is claimed and no new subject matter was introduced with these drawings.

The specification was amended for reasons of grammar and/or syntax, to include references to the drawings, and to bring the specification into a form that corresponds to U.S. conventions and formalities. No new subject matter was added with these amendments. A clean copy of the Specification is included with this petition and a marked-up copy attached hereto.

The claims were amended to eliminate multiple dependencies and to bring them into compliance with the U.S. rules. No new subject matter was introduced with these amendments. A clean copy of the Claims is included with this petition and a marked-up copy attached hereto.

Applicants respectfully request that the amendments to the Specification and Claims, and the new drawings be entered in the application.

Respectfully submitted,

February 20, 2002

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Enclosed:
Substitute Specification
Marked-up copy of Specification
Drawings (2 sheets)

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[Process] Method and Device for the [Manufacture] Production of [Grid] Reticular Structures

This invention [concerns the process for the manufacture of grid structures, especially for the manufacture of metallic grid structures] relates to a method of producing reticular structures, and particularly, to the production of metallic reticular structures, as well as a device suitable therefor.

Reticular structures made [out of] from metal and other materials have a wide range of application. For example, these structures can be used as lightweight structural [building] components [with low weight], battery plates, electrochemical anodes and cathodes, filters for fluids, separation devices for fluid media, [thermal] heat shields and for numerous other uses.

[For the manufacture of these types of structures, numerous processes are known, whereby however, in general an automatic fabrication is only possible with great difficulty. The cause for this, is that with this process, the reticulated foam bodies must be bonded with wax plates. The automated fabrication of the gluing points is either not possible, or possible only with great difficulty.] Numerous methods for producing such types of structures are known. Automated production of such reticulated structures, however, is extremely difficult to implement, primarily because, with the conventional methods, the reticulated foam bodies that serve as patterns or pre-structures must be bonded to wax plates. The step of bonding a foam pre-structure to a wax plate is almost impossible to automate. The [glue points] bonding points are, however, indispensable, since [through these on the one hand, the burning out of the foam pre-structures takes place, and on the other, through the arising connection points, the molten bath in the hollow spaces of the foam pre-structure flows in.] it is through these points that the foam pattern is burned

out and then, through the resulting junctions that the molten metal flows into the cavities or voids formed by the foam pre-structure.

US [patent number] Patent 3,616,841 (Walz; issued 1971), which is viewed as the [nearest state-of-the-art technology, shows a process for the manufacture] closest prior art, discloses a method for the production of an insoluble foam material with a predetermined reticular structure. This [process] method encompasses the steps of producing [manufacture of] a self-supporting reticulated polyurethane foam; [the manufacture of an apyrous mass, in that the hollow spaces of the polyurethane foam are filled with a watery plaster-of-Paris suspension and this suspension cements] producing a refractory mold material by filling the voids of the polyurethane foam with a watery gypsum plaster suspension that then sets; [the] heating [of] the [apyrous mass] refractory mold material to a temperature of about 120° C (250° F) over a time period of two hours; [the production of hollow spaces] producing voids in the [apyrous form mass] refractory mold material by raising the temperature of the refractory mold material [, in which the temperature of the apyrous molding material is raised] to between 535 to 815° C (1,000 to 1,500° F), in order to completely vaporize all of the foam and produce a mold; introducing [; the bringing in of] a molten substance into the refractory mold in an amount sufficient to fill the voids which had been previously [, which consists of metals, metal alloys, ceramics or cement, in the apyrous molding material, whereby the amount of the substance is sufficient, in order to fill the hollow spaces, which had been] occupied by the reticulated foam pre-structure; [solidification of] solidifying the molten substance by reducing the temperature to below[, in that the temperature is so reduced, that it lies below the] melting point of the substance; and [the] washing out [of] the material that constitutes the refractory mold material. The molten substance comprises metals, metal alloys, ceramics, and/or cermet[, which the apyrous molding material constitutes. This process shows several disadvantages].

[The melting of the substance, which is brought into the apyrous molding material, demands great a instrumental expenditure especially with high melting point metals or is technically not feasible.] The method disclosed by Walz has several

disadvantages. The equipment required for melting the substance that is poured into the refractory mold is either very expensive, especially for melting high-melting-point metals, or is technically not feasible. [The structure of the foam is determined by the connection of the foams to the wax plates. The structure of the foam determines the technical parameter of the end product, so that the statistical fluctuation range must be as narrow as possible, in order to guarantee the technical parameters of the end product.] Another disadvantage is that in an automated process it is very difficult to control the bonding of the foam to the wax plate. This step is critical, however, for controlling the quality of the final product, as the quality of the bonding between foam and wax plate determines the structure of the foam pre-structure, which, in turn, determines the technical parameters such as surface smoothness or dimensional accuracy, of the end product. Thus, in order to reliably obtain an end product that corresponds to specification with regard to surface smoothness or dimensional accuracy or other parameters, it is imperative that this step be controllable in order to restrict the statistical range of fluctuation in the structure of the foam as much as possible. [Moreover, it is necessary, in order to fill the branched hollow spaces of the apyrous molding material with a molten bath, to warm the molding material to temperatures, which lie above the melting point of the substance used. This leads to the metal solidifying only very slowly, whereby the solidified metal attains a coarse grainy texture, which causes poor consistency.]

To form the reticular structure, molten metal is poured into the refractory mold, which consists of branched voids. With the Walz method, in order to ensure that the molten metal remains liquid long enough to flow through the branches and completely fill the voids, the mold material must be heated to a temperature higher than that of the melting point of the molten metal. As a result, the solidification of the molten metal progresses very slowly, resulting in a solidified metal with a coarse grainy texture and reduced strength properties.

To solve this problem, [US patent number 3,616,841] Walz suggests various cooling methods, such as, for example, spraying the mold with water or air. [The cooling effect will, however, be substantially weakened, since the molding material hinders

the heat flow.] A problem with such cooling methods is that the mold hinders the flow of heat, thereby significantly diminishing the cooling effect. [Even the manufacture of massive metal areas in common with the grid structure is connected with the problem of the very slow cooling taking place. The given process steps hardly allow a controlled solidification of the metal, in order to attain a bubble-free and fine-grained texture.] Moreover, the production of massive or solid areas of metal together with the reticular structure is related to the problem of a very slow cooling progress. In order to obtain a bubble-free and fine-grained texture, it is imperative that the solidification process of the reticular structure be a controlled process. The method steps disclosed in Walz do not provide a means for effective control over the solidification process. The Walz method has an inherent economic disadvantage that limits the success or feasibility of automating production processes for reticular structures, in that the slow progression of the solidification of the metal results in long process times. [In any case, the slow-going solidification of the metal leads to long process times, which also stand in the way of automated fabrication.]

[Thus, it is the objective of the invention at hand, to so simplify the manufacture of grid structures, that automated fabrication of this type of structure is possible. With this, comes the task of finding a process, which allows the manufacture of grid structures with large dimensions on a large scale.]

What is needed, therefore, is an automated method of production of reticular structures, particularly, metallic reticular structures. What is further needed, is such a method that produces a reticular structure having a fine-grained and bubble-free texture. What is yet further needed is such a method that allows large-scale production of metallic reticular structures, including large-dimensioned reticular structures.

SUMMARY OF THE INVENTION

For the reasons cited above, it is an objective of the present invention to simplify the production of a reticular structure so as to enable automated production. It is a further objective to enable large-scale production of reticular structures, including metallic and/or large-dimensioned reticular structures. It is a yet further objective to enable production of reticular structures having a fine-grained, bubble-free texture.

The objectives are achieved according to the present invention by providing an automated method of producing reticular structures, including large-scale production of metallic and/or large-dimensioned reticular structures and by providing a device for the production of same.

With the method of the present invention, a foam pattern or pre-structure is used to create a refractory mold. The foam pre-structure is placed in a refractory container and infiltrated with a refractory mold material, typically a gypsum plaster suspension. After the mold material has solidified, the resulting mold, including pre-structure, is withdrawn from the refractory container and the pre-structure removed from the mold by volatilization . The mold is then pre-heated to a temperature greater than the melting point of the molten substance that will form the reticular structure and placed inside a heat-resistant container. The molten substance for metallic reticular structures may comprise metals, alloys, ceramics, cermet materials, and/or any suitable combination thereof. [Appropriate to the invention, this is to be attained by a process encompassing the following steps:

(1) Putting of a reticulated foam pre-structure into a hinged container;
(2) Infiltration of the foam pre-structure with an apyrous material;
(3) Solidification of the apyrous material;
(4) Removal of the solidified material out of the hinged container;
(5) Removal of the foam pre-structure from the apyrous material;
(6) Putting of the resulting, pre-warmed body into an apyrous container;
(7) Infiltration of the body with a molten bath;
(8) Removal of the resulting body after solidification of the molten bath ad removal of the apyrous material.]

A key feature of the method and device according to the present invention is that the heat-resistant container is greater in size than the size of the pre-heated mold when it is filled with the molten substance. After the mold is placed in the heat-resistant container and filled with the molten substance, a solid jacket or shell is then poured over the filled mold, filling a gap between the filled mold and the wall of the container. The container wall is temperature-controlled and maintained at a temperature that is lower than the melting point of the molten substance. Since the jacket is in direct contact with the container wall, heat is drawn from the mold through the jacket into the wall and, as a result, cooling begins at the outer perimeter and progresses inward toward the center of the mold. After the molten substance has solidified, the mold is removed from the heat-resistant container and stripped or removed from the cast reticular structure. The ability to control the temperature of the heat-resistant container and of the refractory mold promotes bubble-free solidification of the molten metal.

[Additionally, modification of the surface of the foam pre-structure can be followed by step (1). This is done preferably, by roughing or structuring of the surface of the foam pre-structure. The pouring-in of the molten bath into the apyrous container (step (7)) can take place with pneumatic or vacuum assistance. Subsequent to step (8), the grid structure attained can be cleaned and possibly modified, in that the grid structure is, for example, coated.]

The [process appropriate] method according to the invention offers several advantages. [Gluing of the foam pre-structure to the funnel system and the sprue is no longer necessary. By this, the material and time consumption on the manufacture of casting mould is substantially reduced.] It is no longer necessary to bond the foam pre-structure to the running system and sprue cup. This substantially reduces the time and material required to produce the casting mold. Because large areas of the foam pre-structure are no longer bonded to the running system, the method also eliminates an inherent source of error that resulted from the uncontrollable method of bonding the pre-structure to the running system. The method according to the invention is also economical, as only the amount of

refractory material that is required to produce the mold for the actual reticular structure is used, thus reducing to a minimum the amount of refractory material used in the production of the reticular structure.

The method according to the invention provides additional advantages that improve the quality assurance for the structures. For example, following withdrawal from the first container, the foam pre-structure protrudes from the refractory mold. This simplifies and improves visual monitoring as to whether, after the foam pre-structure is volatilized, the ligaments and cells formed from the pre-structure will be sufficiently well set externally to ensure a complete casting of the reticular structure. Moreover, the accessibility to all sides of the foam pre-structure promotes rapid, even heating of the refractory mold. Ready access to the ligaments and cells of the foam structure also promotes rapid volatilization of the foam pre-structure. After the pre-structure has been volatilized, it is also easier to monitor whether the ligaments provide sufficient means of access of the molten metal to the internal structure, that is, to the „negative mold." [Furthermore, the source of errors, with which the uncontrollable gluing process is connected, lapses, since large areas of the foam pre-structure are not connected with the funnel system. Only the amount of apyrous material is needed, which is necessary in order to manufacture the grid structure. The foam pre-structure protrudes after the removal from the mold container from the apyrous molding material. By this, it is easy to check, if after the vaporization of the foam-pre-body all cell connectors and cells have a sufficiently good external connection, in order to guarantee a complete casting. Beyond this, the accessibility of the foam pre-structure shows advantages from all sides, that the apyrous mould can be heated without delay and that free access to the cell connection and cells of the foam structure make an accelerated vaporization of the foam pre-structure possible. After the vaporization it can also easily be checked, if enough cell connections are intact for access of the molten bath to the internal structure of the „negative mould.„ Since the apyrous material is pre-warmed, before it is laid into the apyrous container, the molten mass hardens from the outside, meaning from the container wall held cooler inward. By targeted temperature guidance of the

container and of the apyrous material, a bubble-free solidification of the molten bath can be made possible.]

The method according to the invention does not require the use of the wax plates to bond the foam pre-structure, as do conventional methods, and allows continuous auotmated, large-scale production of reticular structures. Examples of suitable uses of the metallic reticular structures obtained from the production method according to the invention, include use as catalysts for EMC shielding and in batteries. For example, in the production of a reticular structure for use in a catalytic converter for the combustion stabilization of diesel fuel, the refractory mold is filled with a molten metal comprising a Zn/Cu alloy. Reticular structures produced according to the method of the invention and made of aluminum and then coated with lead are used, for example, in batteries.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates the foam pre-structure that can also be coated.

FIG. 2 shows the first openable container with cover, in which the foam pre-structure is placed according to the method of the present invention.

FIG. 3 shows the first openable container containing the foam pre-structure, whereby the container has been filled with the refractory mold material .

FIG. 4 shows the refractory mold material with the foam pre-structure.

FIG. 5 shows a refractory mold and the cavities that remain when the foam pre-structure has been removed from the set mold material.

FIG. 6 shows the device according to the present invention, including a cooling plate.

FIG. 7 shows the device of FIG. 6 on the cooling plate, with the refractory mold placed in the device, whereby the refractory mold is geometrically smaller than the device.

FIG. 8 shows the reticular structure, formed according to the method and device of the present invention, with a partial jacket casting abutting the reticular structure.

DETAILED DESCRIPTION OF THE INVENTION

To form a reticular structure 22 according to the method of the present invention, a reticulated foam pre-structure 10 is placed in an openable container 12 having a container lid 12A, as illustrated by FIGS. 1 and 2. Preferably, the material used for the pre-structure material 10 is polyurethane foam, although any material that provides a sufficient number of pores is suitable for use as the pre-structure material. The foam pre-structure 10 is then infiltrated with a refractory mold material 14, as shown in FIG. 3. The container lid 12A is closed for applying a vacuum to the openable container 12. The refractory mold material 14 is allowed to solidify to form a refractory mold 16. Preferably, the refractory mold material 14 is a watery gypsum plaster suspension.

The surface of the foam pre-structure 10 is modifiable, preferably by roughening or structuring the surface of the foam pre-structure 10 after it has been placed in the openable container 12. Pneumatic or vacuum assistance may be used to force the refractory mold material 14 into the container 12 to ensure that the material 14 completely encases the pre-structure 10.

After solidification, the refractory mold 16, along with the foam pre-structure 10, shown in FIG. 4, is withdrawn from the openable container 12, and the foam pre-structure 10 stripped or removed from the refractory mold 16. FIG. 5 shows the refractory mold 16, including the voids 17 formed by the foam pre-structure 10.

FIG. 6 shows the device according to the present invention, which is a heat-resistant container 18 mounted on a cooling plate 20. The refractory mold 16 is pre-heated and placed into the heat-resistant container 18. As shown in FIG. 7, the heat-resistant container 16 is geometrically larger than the mold 16. The difference in dimensions between the heat-resistant container 18 and the mold 16 results in a gap 19 between the mold 16 and the heat-resistant container 18. The mold 16 is then infiltrated with a molten substance that fills the voids 19 in the mold 16, thereby forming a reticular structure 22, as shown in FIG. 8. Any suitable casting material may be used in the method according to the present invention. For metallic reticular structures, the molten substance comprises preferably metals, alloys, ceramics, metal ceramics, and/or any suitable combination thereof. After the molten substance has solidified, the reticular structure 22 is withdrawn from the heat-resistant container 18 and the refractory mold 16 removed from the structure 16.

As can be seen in FIG. 8, the reticular structure 22 corresponds in shape to the foam pre-structure 10. Also shown in FIG. 8 is a plate 24 that is formed when a casting material is poured over the mold 16 that is filled with the molten substance and fills the gap 19 between the heat-resistant container 18 and the mold 16.

The heat-resistant container 18 according to the invention holds the mold 16 and has at least one opening 21 for pouring the molten metal into the refractory mold 16. Preferably, the interior space of the container 18 is larger than the pre-heated refractory mold 16 filled with the molten substance, in order to provide a gap between the wall of the container and the refractory mold. The size of the gap is freely-selectable and is determined by the difference in size between the heat-resistant container 18 and the filled, pre-heated mold 16. After pouring the molten substance into the mold 16, a solid jacket or shell is then cast onto the structure, *i.e.*, the mold 16 filled with the molten substance, thereby filling the gap 19 between the structure and the container 18. The container 18 is temperature-controlled and maintained at a temperature that is cooler than that of the molten metal and the pre-heated refractory mold 16. Since the jacket is in direct contact with the container 18, heat is drawn from the casting metal directly into the container 18 during the solidification process, allowing the structure 22 to cool from the outside inward toward the center of the mold 18, thereby producing a cast structure with a fine grain and, also, producing optimal bonding between ligaments 22A of the reticular structure 22 and the solid shell. The reticular structure 22 that is obtained after solidification of the molten substance can then be cleaned and is modifiable, for example, by applying a conventional coating to the structure 22.

The reticular structures 22 produced by the method according to the invention, including the use of the heat-resistant container 18, can be integrated into castings that are produced by various casting methods, such as, for example, die casting, permanent-mold casting, centrifugal casting, low-pressure casting or back-pressure casting. The reticular structures themselves can also be cast by these methods.

The method according to the invention enables automated production of reticular structures 22 of the most varying degrees of fineness with respect to the thickness of ligaments 22A and the size of cells 22B. Combinations of various cell sizes and ligament thicknesses within one structure 22 are also possible.

The method and device according to the invention described herein are merely illustrative of the present invention. It should be understood that variations in the steps of the method and construction of the device may be contemplated in view of the following claims without straying from the intended scope and field of the invention herein disclosed.

[This shows at least one opening for the pouring in of the molten bath into the apyrous material. Preferably, the interior space of the container is larger than the apyrous, preheated material. Between the container wall and the body made out of apyrous material, a freely-selectable gap comes into being, so that a freely formed, massive partition can be poured on the grid structure. This partition is in direct contact with the container wall, so that the solidification warmth from the casting metal can be led off directly in the container wall and a fine-granular casting metal texture is produced. Furthermore, an optimal connection of the cell connection to the grid structure on the massive partition is produced.]

[The grid structures produced by the process with the use of the apyrous container, can be integrated into castings, which can be manufactured with various casting processes, as for example, die casting, permanent-mold casting, centrifugal casting, low-pressure casting or back-pressure casting. Also, grid structures, themselves, can be casted by this process. The process can be conducted continuously, since at this technological level, the necessity of gluing wax plates to the foam pre-structure is passed upon. By the use of the process corresponding to the invention, an automated fabrication of grid structures is made possible.]

[Any material can be used as a foam pre-structure, that shows a sufficient number of pores. Preferably, this material is polyurethane foam. As an apyrous material, the employment of plaster-of-Paris is preferred. The molten bath consists of metals, metal alloys, ceramics or metal ceramics. Any casting material can be used, however.]

[The metallic grid structures produced by the invention, can for example, be employed as catalysts for EMC shielding and in batteries. For example, for the manufacturer of a catalytic converter for the combustion stabilization of diesel fuel, a Zn/Cu alloy is used as a molten bath, with which the aporous material is filled. For example, grid structures produced by the invention can be employed in batteries, which are made out of aluminum and following step (8) can be coated with lead.]

What is claimed is:

1. A method of producing a reticular structure, said method comprising the steps of [Process for the manufacture of metallic grid structures, by which it is qualified that the steps cover]

a) placing a reticulated foam pre-structure into a first container having a lid [Putting in of a reticulated foam pre-structure into a hinged container];

b) infiltrating said [infiltration of the] foam pre-structure with a refractory mold [an apyrous] material;

c) solidifying said refractory material to form a refractory mold [removal of the solidified apyrous material from the hinged container];

d) withdrawing said refractory mold along with said foam pre-structure from said first container [removal of the foam pre-structure from the apyrous material];

e) removing said foam pre-structure from said refractory mold;

f) pre-heating said refractory mold and placing said mold into a second container [Putting in of the resulting, heated body into a heat-resistant container];

g) infiltrating said refractory mold with a molten substance to form a reticular structure [infiltration of the body with a molten bath];

h) after said molten substance has solidified, withdrawing said reticular structure from said second container and removing said refractory mold from said reticular structure [removal of the resulting body after solidification of the molten bath from the heat-resistant container and removal of the apyrous material].

Claims 2 - 7 are cancelled.

8. The method of producing a reticular structure according to claim 1, wherein, after the step of withdrawing said refractory mold from said first container, said foam pre-structure protrudes from said refractory mold.

9. The method of producing a reticular structure according to claim 1, wherein, subsequent to the step of infiltrating said refractory mold with said molten substance, said method includes the step of casting a solid jacket on said refractory mold with said molten substance.

10. The method of producing a reticular structure according to claim 1, wherein said foam pre-structure has a surface and wherein, subsequent to step a), said method includes a step of modifying said surface by roughening.

11. The method of producing a reticular structure according to claim 1, wherein said foam pre-structure has a surface and wherein, subsequent to step a), said method includes a step of modifying said surface by texturing.

12. The method of producing a reticular structure according to claim 1, wherein said reticular structure has a structure surface and wherein, subsequent to step h), said method includes a step of modifying said structure surface by applying a coating to said structure surface.

13. A device for producing a reticular structure according to claim 1, wherein said second container has a container wall and at least one opening for pouring in said molten substance, and has an interior space that is sufficiently large to provide a gap between said pre-heated refractory mold filled with said molten substance and said container wall.

14. The method of Claim 1, wherein said reticular structure is a metallic reticular structure and said molten substance is a molten metallic substance

comprising materials from a group consisting of metals, metal alloys, ceramics and cermet.

15. The method of Claim 1, wherein said foam pre-structure is a polyurethane foam.

16. The method of Claim 1, wherein said refractory mold material comprises a gypsum plaster suspension.

17. The method of Claim 1, wherein said first container is made of a refractory material.

18. The method of Claim 1, wherein said second container is made of a heat-resistant material.

ABSTRACT

A method of producing reticular structures, particularly metallic reticular structures, as well as a device suitable for the production thereof. The method and device enable continuous and/or automated production of such structures, and particularly, large-scale automated production of large-dimensioned reticular structures. A reticulated foam pre-structure is placed into a first container and infiltrated with a refractory material. After solidification, the mold formed by the refractory material is removed from the first container and the foam pre-structure stripped from the mold. The mold is then pre-heated and placed into a second container and infiltrated with a molten substance that forms the reticular structure when solidified. The filled mold may be covered with a solid jacket as a means of controlling the rate and progression of solidification of the molten substance to form a fine-grained, bubble-free structure.

[The invention concerns a process for the manufacture of gird structures, especially out of metal, as well as a device appropriate for it. The objective of this invention is the manufacture of grid structures to so simplify the manufacture, that an automated fabrication of these is possible. With this, the task of finding a process is given, one which allows the manufacture of grid structures with large dimensions on a large scale. Appropriate to the invention, this is attained as the following steps are executed:]

[(1) Putting of a reticulated foam pre-structure into a hinged container; (2) Infiltration of this structure with an apyrous material; (3) Solidification of the material; (4) Removal of the solidified material from the hinged container; (5) Removal of the foam pre-structure; (6) Putting in of the resulting, preheated body into a heat-proof container; (7) Infiltration of the body with a molten bath and (8) Removal of the resulting body after solidification of the molten bath and removal of the apyrous material. The device consists of an apyrous container, whose interior space is larger than the apyrous pre-heated body.]